M.O. 514 AIR MINISTRY

METEOROLOGICAL OFFICE

THE METEOROLOGICAL MAGAZINE

VOL. 78. No. 929. NOVEMBER 1949

PRESSURE IRREGULARITIES ON AUGUST 23–24, 1944

By C. K. M. DOUGLAS, B.A.

Some unusual irregularities of pressure were observed on August 23–24, 1944. One of these crossed Birmingham at about 0735 G.M.T. on the 23rd and attracted attention because of its effect on gas pressures. A copy of the barograph trace at Edgbaston Observatory, kindly supplied by Mr. A. L. Kelley, is reproduced in Fig. 1a, and the anemometer trace in Fig. 2a. There was a sharp rise of pressure of $2\frac{1}{2}$ mb. accompanied by a brief squall from SSW., followed within a few minutes by a fall of pressure to its original value, and a return of the easterly wind, though there was some permanent veer and decrease.

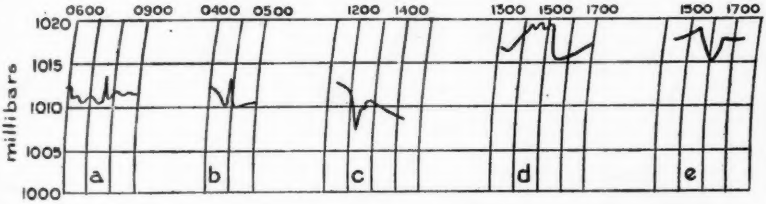

FIG. 1—BAROGRAPH TRACES, AUGUST 23–24, 1944

a.—Edgbaston, August 23 b.—Boscombe Down, August 23
c.—Killadeas, August 23 d.—Felixstowe, August 24
e.—Dunstable, August 24

The chart for 0800, Fig. 3, shows an irregular pressure distribution with a shallow depression off our south-west coasts, which was moving north and being absorbed by a trough coming in from the west. The hourly charts showed no simple sequence. There was a layer of low stratus from the North Sea with a temperature inversion above it. The squall was associated with a cold front between 900 and 800 mb. At Larkhill the temperature at 900 mb. was 65°F. at midnight, falling to 58° at 0600 and to 53° at noon. Above the 800-mb. surface the temperature difference was eliminated by subsidence behind the front. The 0600 sounding at Larkhill, in rain behind the squall, shows deep damp air and a saturated adiabatic lapse rate. None of the soundings in the British Isles showed appreciable actual or potential instability, but there must have been some instability at the front, which gave thunderstorms and heavy

rainfall over a large area in the west. Boscombe Down had 19 mm. of rain in 9 minutes shortly before 0500 G.M.T., and the brief squall accompanying it gave a gust of 62 m.p.h. The barograph trace, Fig. 1*b*, was similar to that at Birmingham. At London and Dunstable there was only a slight shower, but the barograph showed a line-squall effect, though there was no actual squall, but only a temporary change to a light southerly wind. All over the area affected by the squall the wind returned to E. afterwards, but there was some permanent veer and decrease of wind. A further veer occurred some time later as the trough of low pressure moved north, with a wedge of high pressure spreading northward behind it. In spite of very high surface dew points this trough gave no rain. The speed of the front was about 30 kt. in the west but in the east it was somewhat less.

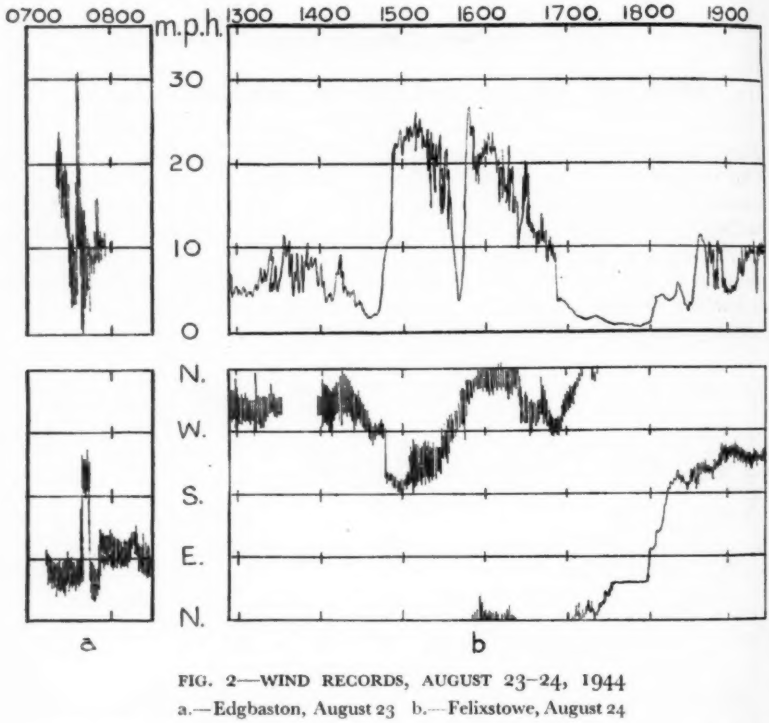

FIG. 2—WIND RECORDS, AUGUST 23–24, 1944

a.—Edgbaston, August 23 b.—Felixstowe, August 24

At 0600 the remains of a warm front extended from the southern end of Cardigan Bay to The Wash. This had a history and was still associated with a slight difference of surface temperature and dew point, but it had become poorly related to the general thermal field and was afterwards dropped. There was, however, some northward decrease of temperature at 900–800 mb. in the air ahead of the front, and Squires Gate was the most northerly station to show a line-squall effect. Rain crossed west and central Scotland with thunderstorms in places but frontal effects were weak.

The line of rain crossed Ireland, and at Killadeas (Co. Fermanagh) there was a fluctuation of pressure of the opposite kind to that observed in England. Pressure fell $4\frac{1}{2}$ mb. in about 20 min. Fig. 1c shows a copy of the barograph trace. It occurred during continuous rain, and the E. wind became temporarily rather squally.

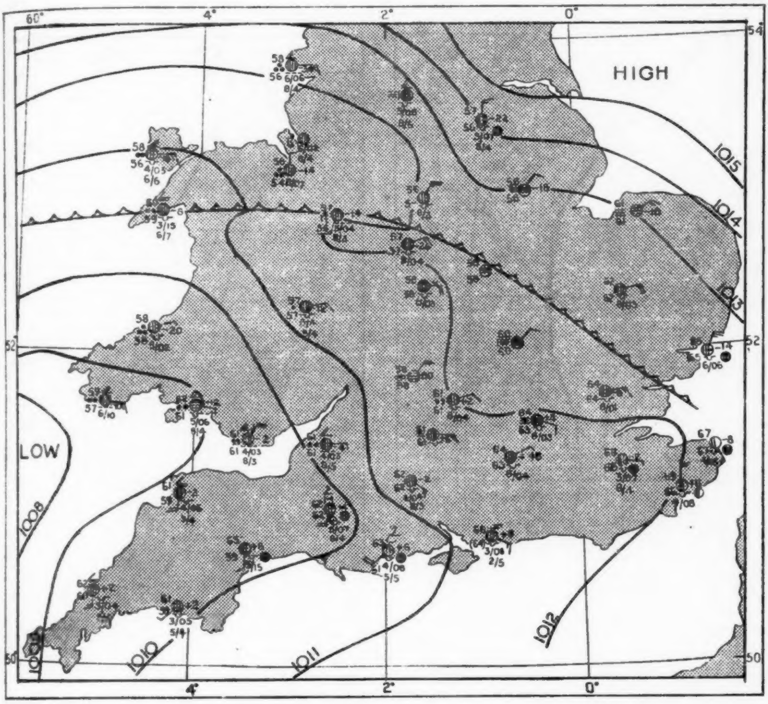

FIG. 3—SYNOPTIC CHART, AUGUST 23, 1944, 0800, SHOWING UPPER COLD FRONT

The Director of the Meteorological Service of the Irish Free State was good enough to send copies of the autographic traces from a number of places in Ireland. The trough was nowhere so pronounced as at Killadeas, but it showed at Dublin (depth 2 mb.), Baldonnel and Mullingar. At Aldergrove it only just showed and was very weak. The aircraft sounding at that station, Fig. 4a, showed that instability was on a small scale only, both in amount and in the depth of the layers affected.

Further remarkable fluctuations of pressure took place in the eastern and midland districts of England on August 24, associated with high-level thunderstorms. At Yarmouth pressure fell $4\frac{1}{2}$ mb. in half an hour at 0200. At Felixstowe most of the fall shortly after 1500, Fig. 1d, was even more abrupt, but the recovery was much slower than the fall. The wind record, Fig. 2b, shows that during the fall of pressure there was complete lack of balance between the wind and the gradient. Part of the fall may have represented development

rather than movement. The same disturbance affected a large area extending from the east Midlands to Yarmouth and from the south-east coast to Cranwell and Spurn Head. In general the fall of pressure was less abrupt than at Felixstowe, but nevertheless the trough was a notable one. There was a pronounced rise of pressure at the beginning of the rain, followed by a rapid fall to a minimum about or just before the end of the rain. Fig. 1e shows a copy of the Dunstable barogram with a fall of $4\frac{1}{2}$ mb. in half an hour. The

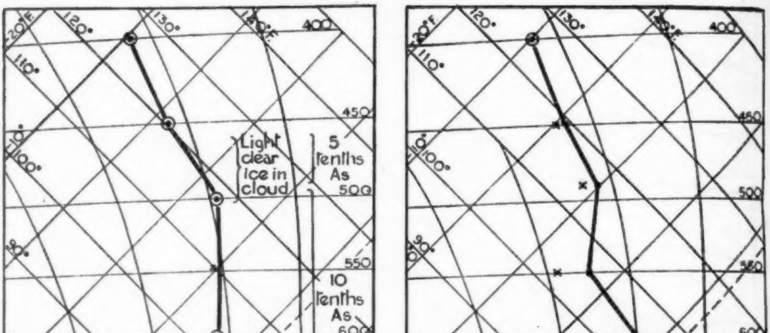

FIG. 4—TEPHIGRAMS, AUGUST 23–24, 1944
a.—Aldergrove, August 23, 1040 b.—Downham Market, August 24, 1800
Wet-bulb readings shown by crosses

trough occurred just an hour later than in London (Kingsway) giving a speed of 27 kt. This may be compared with the winds at medium levels at Downham Market and Larkhill, given in Table I. The duration of the rain ranged up to just over two hours, and taking a speed of 27 kt. this gives the rain belt a width ranging up to 65 miles. Amounts in this storm ranged up to at least 28 mm. The available information does not fit into any simple pattern, which one could hardly expect in the case of an instability phenomenon, but there is evidence of elongation across the vertical wind shear. At 1800, Fig. 5, Spurn

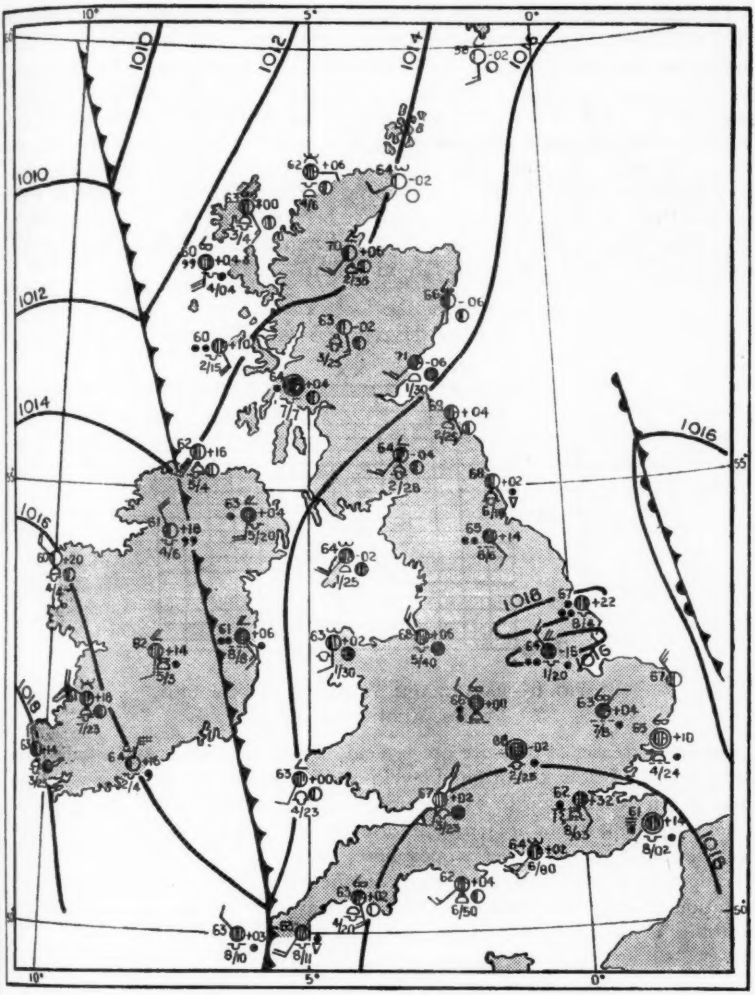

FIG. 5—SYNOPTIC CHART, AUGUST 24, 1944, 1800

Head was in the high-pressure region and Cranwell in the trough of low pressure. Elongated systems are indicated, but the material for determining their exact nature, if it ever existed, is no longer available.

The cold front of the previous day had become quasi-stationary over the North Sea by 1800 on the 24th, Fig. 5. A wedge had spread from the north and the thunderstorm system with its pressure irregularities had invaded the wedge from south-south-east. The SSE. upper wind was ahead of an upper trough, which had passed Larkhill by 1800 and which crossed south-east England during the night, with further rain. The 1800 sounding at Downham Market, Fig. 4b, shows marked instability above the 650-mb. surface.

Through the courtesy of the Directors of the French and Belgian Meteorological Offices, copies of barograph traces were obtained from the observatories at Montsouris, Paris, and at Uccle, Brussels. The Paris curve, Fig. 6, shows a rise of 5·7 mb. (4·3 mm.) between 1940 and 2000 on the 23rd, immediately followed by a fall of 2·7 mb. in 12 min. This storm affected Kent and East Anglia during the night; the fall of 4½ mb. in half an hour at Yarmouth was associated with the same storm or group of storms. There were also small irregularities at Paris during the morning of the 24th, when the storm which reached England that afternoon must have been crossing the area or developing in it. The Uccle trace also shows marked irregularities on the 23rd and 24th, in particular a large rise just before midnight.

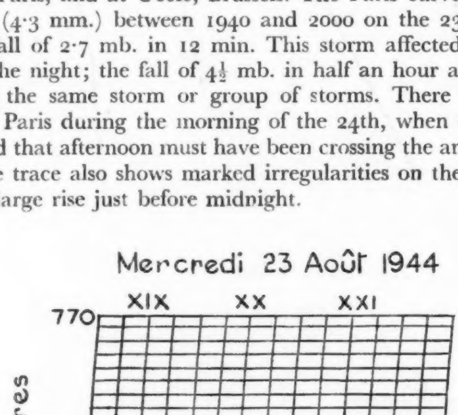

FIG. 6—BAROGRAPH TRACE AT MONTSOURIS, PARIS, AUGUST 23, 1944

Sudden increases of pressure are typical of thunderstorms, and a subsequent fall back to, or below, the original level is quite common, though this is rarely so rapid as on August 23rd. Pronounced small troughs on the barograph are rather infrequent in our area, and are usually associated with large vertical wind shear (at least in the lower troposphere) and with medium-level instability. Considerable fluctuations may occur in these conditions even when no precipitation reaches the ground. The Killadeas case shows that medium-level instability is not an essential feature for the formation of a small low.

TABLE I—UPPER WINDS

Pressure	August 23 Larkhill		Liverpool		August 24 Larkhill				Downham Market			
	0600		1200		1200		1800		1200		1800	
mb.	°	kt.	°	kt.	°	kt.	°	kt.	°	kt.	°	kt.
500	160	48	160	60	150	33	260	13	160	57	130	57
550	160	49	160	59	150	26	270	13	160	53	140	52
600	160	54	160	57	160	25	260	10	150	41	140	35
650	160	55	160	53	160	20	250	9	160	39	150	23
700	150	50	160	44	170	17	250	8	160	35	150	20
750	150	47	150	43	190	17	230	8	170	24	140	19
800	150	42	160	40	190	16	220	3	160	19	140	17
850	140	32	160	36	180	12	230	8	170	12	120	13
900	130	26	160	31	180	10	240	8	190	6	360	15
950	100	17	130	27	180	9	220	7	260	3	340	—

NOTES ON SOUTHERN HEMISPHERE CIRCULATION

By S. T. A. MIRRLEES, M.A.

Observations in Graham Land.—Records of some two years' meteorological observations in West Graham Land, Antarctica, have been put at the disposal of the Meteorological Office by Mr. A. Stephenson, Chief Surveyor and Meteorologist to the British Graham Land Expedition, 1934–37.

Mr. Stephenson[1]*, as is known to readers of this Magazine, has had considerable previous experience of "higher latitude" meteorology, and his records are more comprehensive than those of most expeditions which have not included a full-time meteorologist. War and other circumstances, however, have delayed preparation of the full meteorological account of the expedition, and this note gives the results only of a preliminary examination of some of the barometric data, directed mainly to a search for "circulation patterns".

Barometric pressure over Graham Land, 1935–37.—Table I, which is extracted from Mr. Stephenson's notes published in the *Geographical Journal*[2] soon after the return of the expedition shows the mean barometric pressure at mean sea level for various months at the two bases Argentine Islands and Barry Island. Data for February 1936 are missing as the expedition was shifting camp in that month.

TABLE I—MEAN MONTHLY BAROMETRIC PRESSURE AT MEAN SEA LEVEL

A: Argentine Islands, 65° 15′S., 64°16′W., 110 ft., March 1935 – January 1936
B: Barry Island, 68°08′S., 67°06′W., 50 ft., March 1936 – February 1937

	Period	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mean
							millibars							
A	1935–36	*973·9*	993·2	991·5	995·1	**997·9**	991·1	996·8	994·3	986·3	992·2	993·9	..	991‡
B	1936–37	979·8*	989·2	993·2	993·3	991·3	**994·7**	*979·7*	989·3	982·7	981·7	990·2	991·6†	988

*March 12–31, 1936 †February 1–23, 1937 ‡Mean of 11 months

In comparison with the data given in the standard work by Meinardus[3] the range of the means for station A (24 mb.) is slightly greater than had been observed before in Graham Land. The great variability from month to month, small variability from year to year (annual pressure little different from 987 mb. (740 mm.)) and the tendency for a double annual period are characteristic of Antarctica. The mean for March 1935 (973·9 mb.) is 6 mb. lower than had been observed in Graham Land for any month before 1935.

General circulation (surface) of the "fifties" and "sixties".—The main features of the general circulation over the region southward of South America are well known in a broad way as

(*a*) a region of prevailing westerly winds with mean pressure decreasing southwards;

(*b*) a trough of low pressure, statistically the "mean path of depressions", somewhere between 60° and 65°S., but exactly where remains to be determined; and

(*c*) a region of prevailing easterlies with mean pressure increasing southwards (?) from 65°S.

*These numbers refer to the list of references on p. 321.

Up to about 1935 published data of observations for the region south of 61°S., where the most southerly fixed station (in the South Orkneys) is situated, included observations at three fixed stations for separate periods 1902–03, 1904–05 and 1908–09 and a number of "ship drifts". Synoptic charts of the southern hemisphere between 30°S. and Antarctica were published for October 1901 to March 1904 based on the results of various expeditions, but much detail remains to be filled in, particularly on the tracks and speed of travel of depressions southward of 55°S.

Comparison of data for 1935–37.—The first stage in this preliminary comparison was to collect, from the various year-books, etc., data, for the period of Table I, for as many stations as could be found for which more or less long-period normals were available. These "permanent" stations are shown in Table II and Fig. 1.

TABLE II—"PERMANENT" STATIONS FOR WHICH NORMALS ARE AVAILABLE

Station	Latitude S.	Longitude W.	Height ft.
Punta Galera	40°01′	73°44′	131
Isla Guafo	43°34′	74°45′	459
Cape Raper	46°50′	75°38′	131
Islota de Los Evangelistas	52°24′	75°06′	180
Punta Arenas	53°10′	70°54′	92
Ushuaia	54°50′	68°20′	26
Puerto Madryn	42°46′	65°02′	46
Sarmiento	45°33′	69°01′	597
Santa Cruz	50°01′	68°31′	43
Punta Dungeness	52°24′	68°26′	16
Port Stanley (Falkland Is.)	51°42′	57°51′	6
South Georgia	54°16′	36°30′	13
South Orkneys	60°43′	44°47′	23

From these data it was possible to make charts of normal and actual pressure distribution for various months, also charts of pressure difference from normal and diagrams of the departure from normal of the "gradient" between various pairs of stations (see Figs. 2 and 4).

The mean annual isobars in Fig. 1 are based on all available data whether for long periods or for single years, and the first problem for the future is whether this pattern of isobars represents long-period conditions south of 61°S. or is merely coincidental.

Examination of data for individual months gives some confirmation of the result quoted by Meinardus that there is a reverse variation of monthly mean pressure in South Polar regions as compared with northward of 60°S., but the rule is not invariable; for example, March 1935, the month of lowest pressure at station A, was also that of lowest pressure in the same period at all stations south of 50°S. except at South Georgia, and in October 1935, the month of highest pressure at all mainland stations except Punta Galera, Isla Guafo, Cape Raper, the pressure at station A was above the mean for the year. Whether the correct interpretation is that the exceptions to the rule are occasional months in which the weather systems are much larger than usual remains to be investigated.

Circulation when pressure is relatively high over Graham Land.—Fig. 2 is the " composite situation " of the six months in which pressure over Graham Land was higher than at South Orkneys. These months showed a tendency for

(*a*) prevailing southerly winds at station A;

(*b*) weakened westerly circulation between Guafo and Los Evangelistas; and

(*c*) increased south-west circulation between Falkland Islands and South Orkneys and South Georgia, also between Ushuaia and South Orkneys.

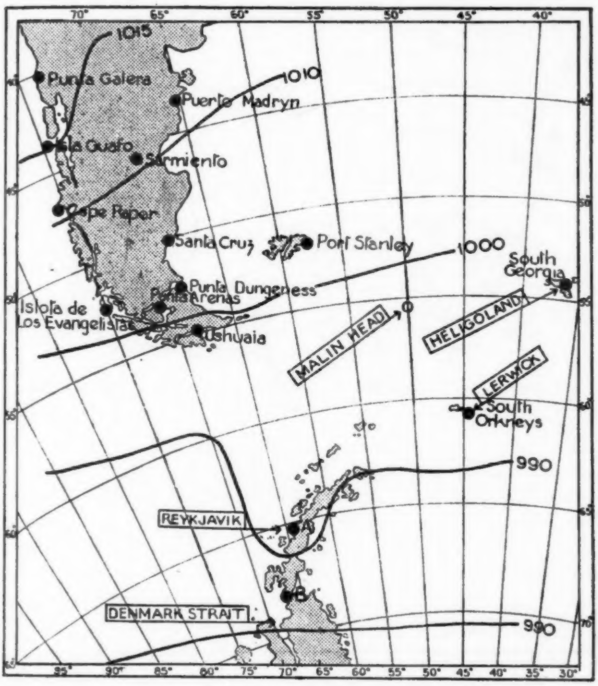

FIG. 1—ISOBARS OF NORMAL ANNUAL BAROMETRIC PRESSURE AT M.S.L.

The stations named (except A and B) are those for which normals are available. A and B mark the positions of the two stations of the British Graham Land expedition

The names of the northern hemisphere "corresponding" station inset enable comparison of relative distance to be made

A possible interpretation is that in these months there was a northward extension of the Weddell Sea low, with, on the western side of the area, either a weakening of the Bellingshausen Sea low or its displacement considerably southward and an opening out of the gradient for westerly winds between Punta Galera and Los Evangelistas, rather than a southward extension of the South Pacific high. It may be noted that the " composite situation " based on seven months with greatest area of positive deviation of pressure is almost identical with Fig. 2.

Circulation when pressure is generally below normal.—The reverse situation, in which pressure was below normal at 11 or more of the 13 "permanent" stations (10 months out of 24) was accompanied (in six months) by prevailing winds between E. and S. at the stations A and B, increased westerly circulation in the zone between Guafo and Los Evangelistas and decreased SW. circulation in the east of the area; further, when the westerly circulation was enhanced in both northern and southern parts of the zone (three months) the gradient for SW. winds in the east of the area was much weakened or even reversed.

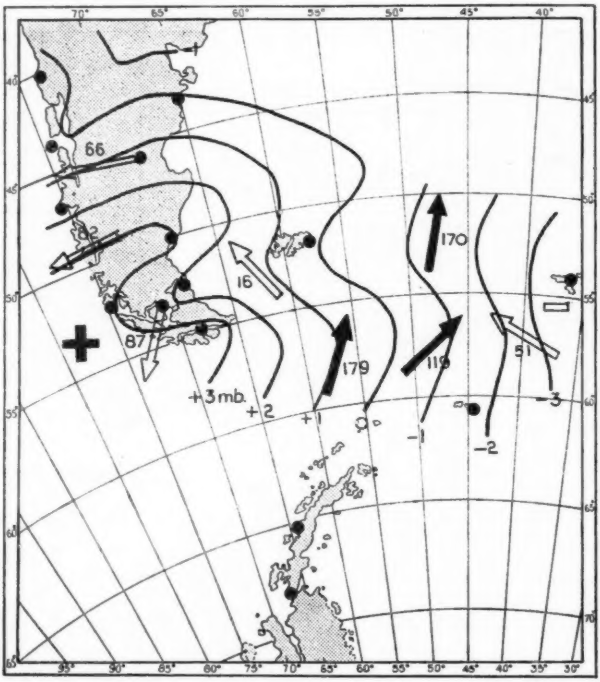

FIG. 2—"COMPOSITE" CIRCULATION PATTERN. MEANS OF SIX MONTHS IN WHICH PRESSURE OVER GRAHAM LAND WAS HIGHER THAN OVER SOUTH ORKNEYS

The continuous lines are isonormals. Arrows fly with excess (thick lines) or deficit (double lines) "gradient" between pairs of stations; the adjoining figures show the percentage of the "normal gradient"

Limitations of the data.—In view of the short period of observations, which restricts the possibility of sorting out seasonal variations, it does not seem necessary to pursue the search for "types" further on these lines; little emphasis has been laid on data of wind direction because of a statement of marked local influence at the station B.

Extrapolation of normals.—For further investigation of a circulation index it is now necessary to resort to extrapolation. In this connexion, analogy between northern and southern hemispheres is unlikely to be of much use (see Fig. 3); the superposed names of "corresponding" places of the northern

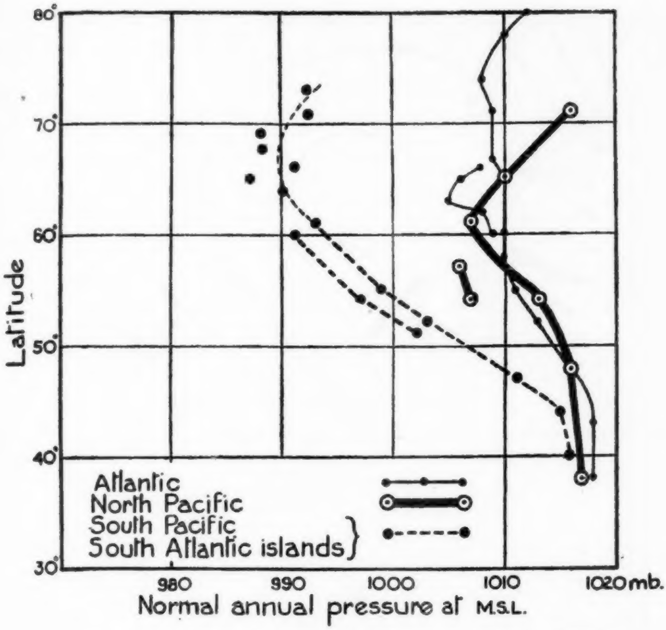

FIG. 3—VARIATION OF NORMAL PRESSURE WITH LATITUDE IN THE NORTHERN AND SOUTHERN HEMISPHERES

hemisphere on Fig. 1 give an idea of the distances involved. With this preliminary caution and on the basis that things are simpler in the southern hemisphere one may try extrapolating over the distance from Lerwick to Reykjavik. Incidentally, the much stronger circulation of the southern hemisphere seems to be associated with a lower height of tropopause; the radio-sonde ascents made to date in the Falkland Islands have shown a tropopause height on the average 1 Km. lower than in England in the same latitude.

First, an attempt was made by extrapolating pressure-anomaly lines for all the months available, to deduce long-period normals of pressure over West Graham Land.

The results of this process are given in Table III along with other estimates quoted from text-books. The main point which remains to be settled by future observations is whether the annual minimum of pressure south of 65°S. is in November, as at South Orkneys, or in some other month.

TABLE III—ESTIMATED "NORMAL" MONTHLY SEA-LEVEL PRESSURE IN 67°S. 65°W.

Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Year	Authority
					millibars								
987	990	995	992	993	991	986	991	982	991	989	991	990	1
985	..	989	..	..	..	989	..	989	..	988	..	..	2
..	..	..	..	..	..	..	..	..	..	990	995	..	3
987	987	991	993	992	991	990	990	992	995	995	990	(991)	4

Authorities.—1. Estimated from observations 1935–37
2. From diagrams in "Handbook of meteorology"[4]
3. From diagrams in "Manual of meteorology"[5]
4. Mean of observations at Port Charcot and Snow Hill[6]

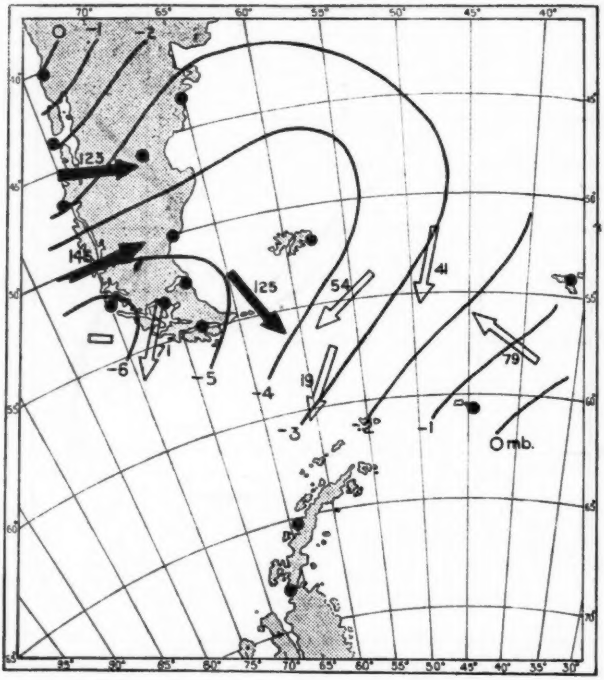

FIG. 4—"COMPOSITE" CIRCULATION PATTERN. MEANS OF SEVEN MONTHS IN WHICH THE "GRADIENT" BETWEEN GUAFO AND LOS EVANGELISTAS WAS ABOVE NORMAL AND THE BREADTH OF THE W.-WIND ZONE (SOUTHWARD OF 55°S.) WAS BELOW NORMAL

(see Table V)

Next, by means of monthly charts of normal pressure distribution and of pressure distribution in 1935–37, estimates were made of the extent of the gradient for westerly winds across the 65th meridian, south of the 55th parallel. The results are given in Table IV. Two rather slight correlations were noted in this comparison:—

(*a*) Months in which the W.-wind zone southward of 55°S. is above normal in both extent and intensity are months in which pressure is generally above normal over the area of Fig. 1, and

(*b*) Months in which westerlies are strong between Guafo and Los Evangelistas are occasions of narrow W.-wind zones southward of 55°S.

TABLE IV—ESTIMATED BREADTH OF W.-WIND ZONE

Measured across 65°W. south of 55°S.

	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
	degrees of latitude											
Normal	11	9	8	8	9	9	13	10	12	10	10	9
1935–36	7	10	12	3	10	7	6	10	5	3	3	11
1936–37	10	10	8	8	9	9	13	10	13	7	8	5

The " composite situation " for seven months of the second type is shown in Fig. 4; the complete frequency distribution is given in Table V, which may be interpreted as an aspect of the see-saw of pressure between lower and higher latitudes noted by various authors.

TABLE V—RELATION OF WESTERLY CIRCULATIONS NORTH AND SOUTH OF 55°S.

Mean monthly gradient between Guafo and Los Evangelistas	Above normal			Below normal		
Breadth of W.-wind zone southward of 55°S.	Above normal	normal	Below normal	Above normal	normal	Below normal
			months			
Frequency of occurrence	0	4	7	6	3	4

Need for further observations and investigations.—A brief examination was made of corresponding data for Reykjavik, Lerwick, Malin Head and Valentia, to see if any evidence would appear of resonance between the westerlies of the northern and southern hemispheres, but the results were inconclusive, as was probably to be expected.

The search for circulation types of the southern hemisphere described above results in more questions than answers, and some other questions, which require a " synoptic " investigation, are:—

(*a*) Can the isobars of Fig. 1 be explained in terms of depression tracks, or are they merely the result of too few observations?

(*b*) Is the " main track " of depressions further south than previously described? and

(*c*) Are the depressions mainly complex? *i.e.* are there two main tracks, one north and one south of 65°S.?

The autographic records of stations A and B would enable a good deal of the frontology there to be deduced, but the start of a real attack on the problems of the circulation in 50–60°S. must await the establishment of an upper air station somewhere south of the circumpolar trough. A single upper air station would give some indications of the " vast circumpolar whirl " described in text-books, but there would still be room for extrapolation—Antarctica is about double the area of Australia.

REFERENCES

1. London, Meteorological Office. The British Polar Expedition to Fort Rae. *Met. Mag., London*, **67**, 1932, p. 249.
2. STEPHENSON, A.; Notes on the scientific work of the British Graham Land expedition: Meteorology. *Geogr. J., London*, **91**, 1938, p. 518.
3. KÖPPEN, W. and GEIGER, R.; Handbuch der Klimatologie. Band IV, Teil U. Klimakunde der Antarktis, by W. Meindardus. Berlin, 1938.
4. BERRY, F. A., BOLLAY, E. and BEERS, N. R.; Handbook of meteorology. New York and London, 1945.
5. SHAW, SIR NAPIER; Manual of meteorology. Vol. II. Comparative meteorology. Cambridge, 1936, pp. 219–41.

THE FORMATION OF A LAMINATED TROPOPAUSE AND THE MASS EXCHANGE BETWEEN THE STRATOSPHERE AND THE TROPOSPHERE

By E. KRAUS

Upper air over east Anglia at 1800 on November 9, 1944.—The immediate incentive for the writing of this note came from the demand to explain the following observations. On the evening of November 9, 1944, several aircraft reported very low condensation trails over the North Sea and East Anglia. These trails disappeared at a height of about 24,000 ft. At about 29,000 ft. the trails were again observed, and they were seen to form throughout the whole layer to above 35,000 ft., which was the highest level of observation. There were also some patches of thin cirrus in layers at about 33,000–34,000 ft.

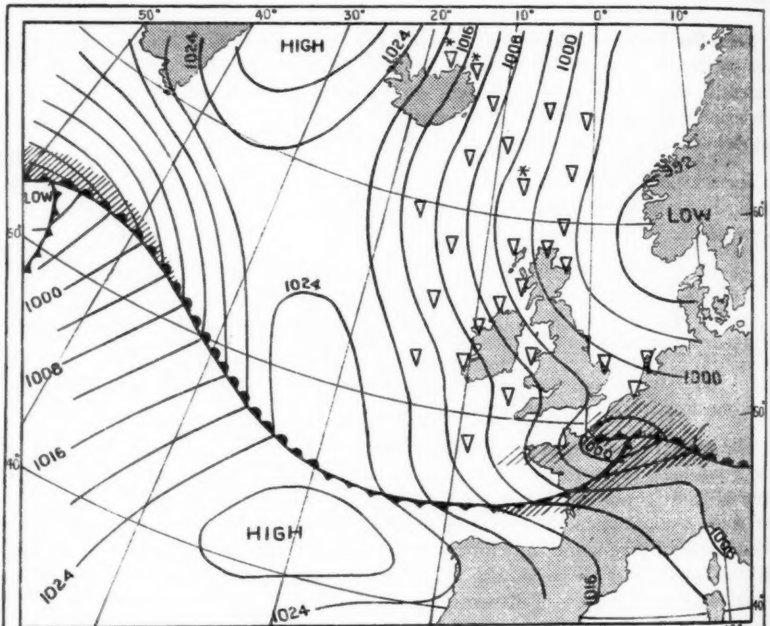

FIG. 1—SURFACE WEATHER CHART, NOVEMBER 8, 1944, 1800

The readings of the radio sounding at Downham Market at 1800 G.M.T. are representative of the air mass in which these observations were made. These values are plotted in Fig. 4. A superficial examination of the ascent curve would suggest that the pressure at the tropopause was 410 mb. and the height 21,300 ft. In the *Daily Weather Report* these values are stated to represent the tropopause. If this statement were complete it would mean that cloud existed in the stratosphere, 12,000 ft. above the tropopause. This is hardly acceptable and a further examination of the radio winds suggests a different picture.

As a rule the wind strength increases in the upper half of the troposphere. This is due to the cumulative effect of the horizontal temperature differences which give rise to a thermal wind which increases with height. In the stratosphere the thermal gradient is reversed and the wind strength decreases again. At the tropopause the values of the wind strength reach a maximum. Therefore at the tropopause we have $\partial v/\partial z = 0$ and there should be no shear across that surface.

Consider now the observed wind at Downham Market:—

TABLE I—RADIO WINDS AT DOWNHAM MARKET AT 1800 G.M.T. ON NOVEMBER 9, 1944

	Pressure (mb.)												
	900	800	700	600	500	400	350	300	250	200	170	150	130
	degrees												
Wind direction	320	330	330	330	330	340	340	340	340	330	330	330	320
	knots												
Wind speed	42	41	53	39	56	76	92	120	104	85	53	40	38

These winds show no maximum near the apparent tropopause at 410 mb. On the contrary, there is a rapid increase of wind above that level to a maximum which seems to be between the 300-mb. and 250-mb. levels at about 30,000–32,000 ft. It follows that either the assumption of a tropopause at 410 mb. is incorrect or that the ascent pierced the tropopause again at a higher level. This question cannot be decided from local data only.

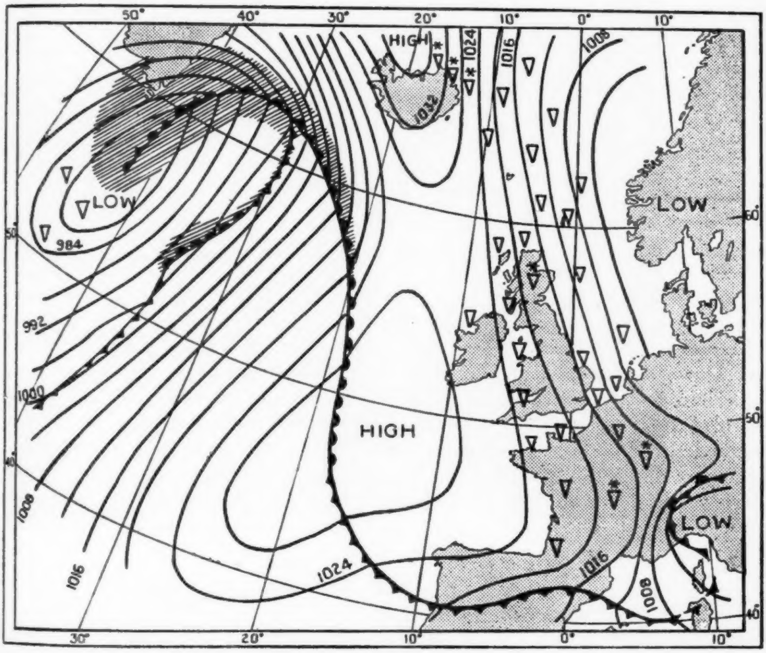

FIG. 2—SURFACE WEATHER CHART, NOVEMBER 9, 1944, 1800

Air-mass analysis.—The synoptic situation on the surface is represented by the two charts Figs. 1 and 2. On the evening of November 8, 1944, a wave depression moved eastward over France and from its centre a front curved westwards across the North Atlantic to another depression which approached Greenland from the south. At 1800 on the following day cold polar continental air in the rear of the wave had invaded Great Britain to a great depth and had broken into the Mediterranean. An anticyclone developed very rapidly to the west of Ireland and the warm front of the next depression approached Iceland.

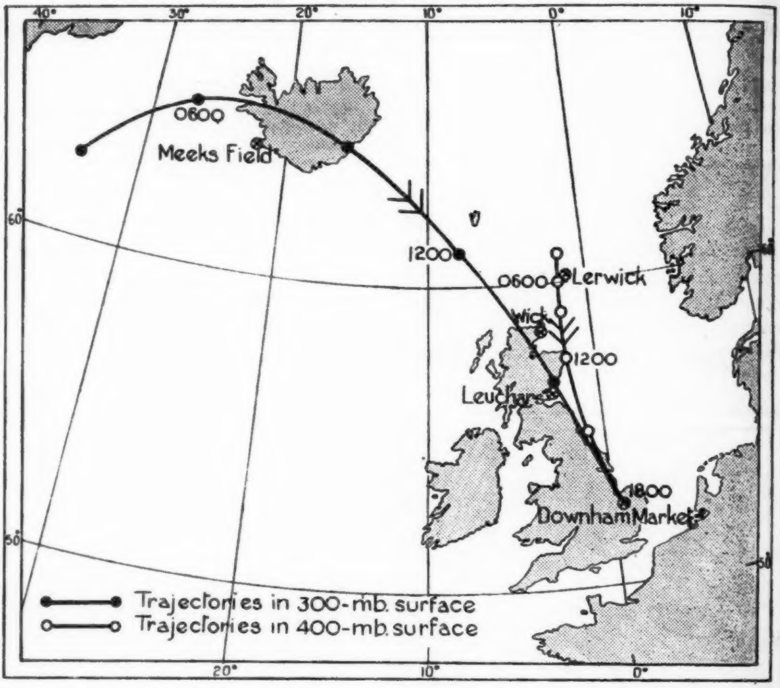

FIG. 3—TRAJECTORIES IN 300-MB. AND 400-MB. SURFACES

In order to ascertain the origin of the air which was at different heights over Downham Market on the evening of the 9th the path of the air to that place had to be reconstructed. This was done by first drawing topographic charts of the 500-, 400- and 300-mb. charts at six-hourly intervals. It was then assumed that for three hours before and after the time of each chart the displacement along the contour lines of an individual body of air occurred very nearly with the gradient wind speed. Curvature and latitude effects were duly considered. The displacement across the isobars was assumed to be equal to:—

$$\frac{1}{\lambda} \times \frac{\text{gradient wind}}{\text{geostrophic wind}} \times \Delta \text{ (gradient wind)}$$

In this expression λ indicates the Coriolis term and " Δ (gradient wind) " is the

Photo by the late Mr. M. C. Gillman

INLAND CLOUD TAKEN FROM A HEIGHT OF 3,500 FT. NEAR THE ZAMBESI DELTA IN THE EARLY AFTERNOON IN MID APRIL

This photograph shows the clear lane which persists along the coast after the early morning " land breeze front " has moved inland and dissipated. The generally fair conditions shown are associated with the tendency for the weather to become settled after the moderate heavy rains which fall in this area during December to March

To face page 324]

Photo by the late Mr. M. C. Gillman

"LIFTING" STRATUS SEEN FROM THE SOUTH-EAST SLOPES OF THE USAMBARA MOUNTAINS ABOUT TWO HOURS AFTER DAWN

This low stratus cloud forming around dawn over the high ground of east Africa sometimes disperses before the morning observation. At dawn it fills the valleys like a sheet of lifted fog and only the lower slopes are covered. At times as it lifts it blankets the higher slopes and can be rather persistent, at others it disperses quickly at low levels. It forms mainly on exposed southern and eastern slopes and breaks sharply to the lee of high ground—*e.g.* over the high ground to the north-east of the Eastleigh airfield at Nairobi

Reproduced by the courtesy of H. E. C. Powers

CIRCUMZENITHAL ARC SEEN FROM WOODFORD, ESSEX, AUGUST 22, 1949, 1800 G.M.T.

Photo by the late Mr. M. C. Gillman

HAILSTORM FRINGE SEEN FROM TARIMI, IKOMA, AT 1700 ON JANUARY 27, 1940

The photograph shows the under mammato surface of a heavy cumulonimbus which was giving rise to a heavy shower of hail, and the effect of local winds associated with violent convection currents is clearly shown by the vegetation. The general level of the ground near Ikoma to the east of Lake Victoria is 1,500–2,500 ft. above the level of the lake (3,700 ft.) with an escarpment a short distance to the east

Reproduced by the courtesy of M. A. Gunn

PARHELIC CIRCLE WITH MOCK SUN AND LINE OF ONE OF THE SHIMMERING WAVES WHICH SWEPT ACROSS THE CIRCLE FROM THE WEST, SEEN FROM GRAYS, ESSEX, JULY 20, 1949, 1020 G.M.T.

(see p. 282)

Reproduced by the courtesy of M. A. Gunn

PARHELIC CIRCLE AND MOCK SUN WITH HALO FORMING, SEEN FROM GRAYS, ESSEX, JULY 20, 1949, 1045 G.M.T.

(see p. 282)

wind change at three-hourly intervals along the path. In computing the path in this manner it had to be assumed that an individual air parcel remained in or near the same isobaric surface. It will be proved below that this assumption was justified in the present special case. The error which is due to the neglect of other small terms should be smaller than that caused by the inaccuracy of the upper air charts.

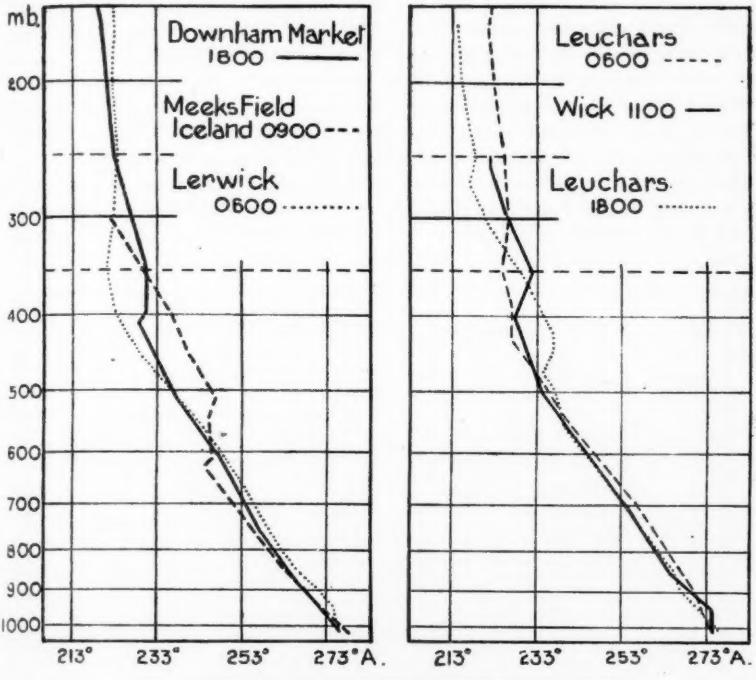

FIG. 4—UPPER AIR ASCENTS, NOVEMBER 9, 1944

The result of the computation is demonstrated in Fig. 3. The air which was over Downham Market at 1800 in the 400-mb. surface slightly above the tropopause was three hours earlier just off Newcastle, and at noon it must have been to the north-east of Aberdeen. The 400-mb. chart for 1200 gives relatively slow wind speeds in that area, and we are led back to a point near Lerwick in the Shetland Isles from where the air must have come six hours earlier, at 0600. At that time the Lerwick radio-sonde indicated slack northerly winds at all heights; at the 400-mb. level the actual values were 360° 13 kt. The curve of the ascent has been plotted on Fig. 4. There seems to be little doubt that the whole air column over Lerwick was of polar origin (polar continental air). The tropopause is at 400 mb. At Downham Market twelve hours later at 1800 it was found to be at 410 mb. It follows from hydrodynamical considerations that the air which is at one time in or near the tropopause should be always near this surface. The assumption that a parcel of air, which was at 0600 at the 400-mb. level over Lerwick, travelled to Downham Market in or near the same pressure level appears therefore justified.

The path in the 300-mb. surface is very different from that in the 400-mb. surface and all lower levels. It should be viewed together with the surface weather charts (Figs. 1 and 2) for it shows the large displacement and the anticyclonic curvature which is typical of the air above a warm front. In twelve hours the air must have covered some 1,400 miles. Because of the lesser accuracy of the upper charts over the North Atlantic the path in the 300-mb. surface cannot be established with the same confidence as that in the 400-mb. surface which was close to the dense aerological network of the British Isles. However, it can be stated with confidence that the position of the air at 0600 was within a 200-mile radius, about the position given in Fig. 3. The whole of western Iceland appears to have been covered at that time by frontal altostratus or cirrostratus, which indicates the presence of warm air aloft. This is confirmed by an examination of the ascent at Meeks Field (Fig. 4), which shows a clearly-marked warm front between 627 mb. and 512 mb. Above the 512-mb. level the sounding reached genuine tropical maritime air. In this air mass was the origin of any sample of air which might have been taken from the 300-mb. surface over Downham Market at 1800 on the same day.

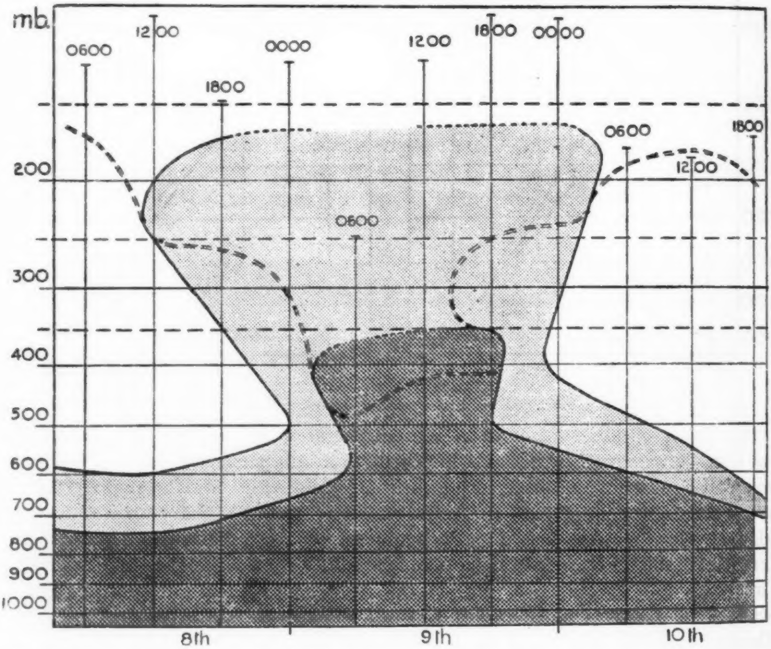

FIG. 5—VARIATION OF THE TROPOPAUSE WITH TIME OVER DOWNHAM MARKET, NOVEMBER 1944

In this way it has been established that on the evening of November 9, over Downham Market the air at 300 mb. was tropospheric air of tropical origin, whilst at the 400-mb. level there was stratospheric air of polar origin. This gave rise to the observed phenomena which were described at the beginning of this note.

There is no evidence that the lower air mass became again uncovered during its further journey. On the contrary, the analysis of the upper charts suggests that the polar air in the 400-mb. surface was the following morning somewhere near Karlsruhe or the northern Black Forest. Whilst travelling there tropical air must have been streaming constantly above it. This is again confirmed by observations from aircrews who reported wispy cirrus and condensation trails above 29,000 ft. in this area on the morning of the 10th. The lower belt of condensation trails had vanished, and it seems that the lower branch of the tropopause, which separated the polar tropospheric from polar stratospheric air, had become diffuse and had lost its character of a discontinuity of the temperature gradient.

The gradual appearance of tropical air aloft is confirmed by an examination of the Scottish ascents which are plotted on the right-hand side of Fig. 4. At 0600 the ascent over Leuchars was made entirely in polar air very similar to that found over Lerwick at the same time. At 1100 tropical air was over Wick above the polar stratosphere at 350 mb. By 1800 the thickness of the tropical air had considerably increased and it was found down to 420 mb. over Leuchars.

Air masses over Downham Market between November 8 and 10.—The passage of the different air masses over Downham Market is illustrated by Fig. 5 and Fig. 6. In Fig. 6 the abscissa has a temperature scale but each successive ascent is displaced by 10°A. to the right; the slanting lines indicate potential temperature; the single arrows give the upper and lower boundaries of the frontal zones, and the double arrows show the height at which the various ascents pierced the tropopause. In Fig. 5 the abscissa has a time scale. The individual ascents are indicated by the vertical lines. The broken double line represents the tropopause and its variation with time. The dark area indicates genuine polar air; the frontal transition layer appears in a lighter shade and the genuine tropical air has not been shaded at all.

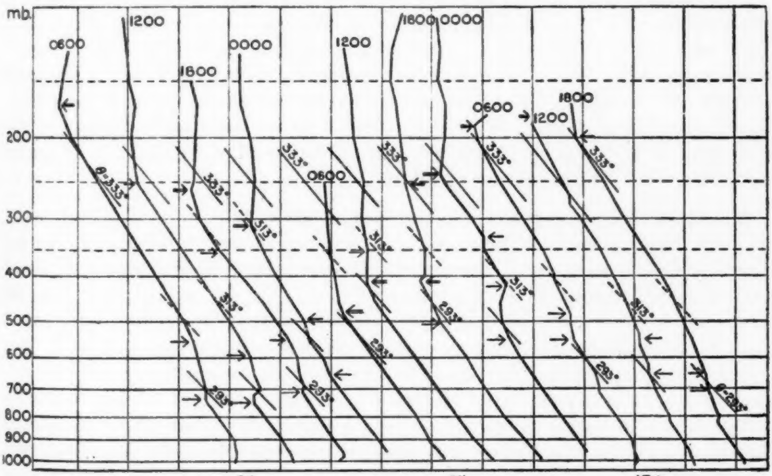

FIG. 6—DIAGRAM ILLUSTRATING THE PASSAGE OF DIFFERENT AIR MASSES OVER DOWNHAM MARKET, NOVEMBER 1944

In the troposphere the frontogenetic processes bring air masses of very different temperature into juxtaposition; therefore we find frequently a narrow zone of very rapid temperature transition which may be called a frontal zone—or in abstraction—a frontal surface. In the stratosphere the horizontal temperature gradient is much weaker, and the horizontal convergence is also much smaller than in the troposphere where it is mostly associated with the rapid up currents of saturated air which do not exist in the stratosphere. Therefore the transition between the air masses is much more gradual, and this is brought out in Fig. 4 by the greater thickness of the transition layer in the stratospheric air.

A more detailed examination of the two diagrams shows that during daylight on November 8—whilst the wave depression which is shown in Fig. 1 was over France—the ascent reached genuine tropical air at about 600 mb. During the night the wave moved away towards the east, and in its rear the depth of the cold air increased rapidly. Transitional stratospheric air appears for the first time aloft in the 1200 ascent. In this transition layer the potential temperature of the tropopause decreases from 337°A. in the genuine tropical air to 313°A. at midnight. At 0600 on the following day the whole ascent is in polar air and the curve of state at that time and at 1200, is almost identical with those found at Lerwick and Scotland in the same air mass. The potential temperature of the tropopause in this polar air is 43° lower than it was twenty-four hours earlier in the tropical air. The re-appearance of tropical air above the polar tropopause at 1800 has been described above. With the slow approach of the warm front from the west the depth of the tropical air increases again, and at 0600 on November 10, the sounding indicates tropical air above 480 mb.; the tropopause has again a potential temperature of 335°A. During the whole development the winds above 200 mb. were relatively slight, and it is reasonable to assume that no real change of air-mass type occurred at very great heights.

The analysis which is presented by Fig. 5 has been fairly well established by the laborious method of trajectory construction, and the investigation of a great number of ascents of which a small fraction only is shown here. It is quite impossible to identify air masses from single observations of the pressure and temperature. This is due to the fact that in the stratosphere, relatively small vertical displacements will cause greater temperature changes than very large horizontal displacements. A simpler method of air-mass identification in the stratosphere may become possible when additional data such as accurate humidity observations become available.

Horizontal convergence in the polar air.—It has been stated above that the lower branch of the tropopause appears to vanish during the further development. Such a dissolution may be due partially to the changed radiational conditions which must be very different from those at the origin of the polar air in higher latitudes. Radiation acts relatively slowly, however, and there is evidence that kinematic effects are more important in the present case. It is well known that vertical divergence in a layer of air causes the vertical temperature gradient to approach the adiabatic lapse rate, and that it tends to smooth out pronounced changes of the lapse rate. Vertical divergence therefore favours the disappearance of a tropopause. In the free atmosphere vertical divergence of any extent is always associated with horizontal convergence, and for that there is ample evidence in our example.

In the first instance it can be observed that the surface pressure is rising briskly over the whole area where the multiple tropopause has been observed or may be expected (*Daily Weather Report*). Theoretically it has been demonstrated by Sutcliffe, Bjerknes and other authors that rising pressure on the ground is always associated with horizontal convergence and vertical divergence aloft. In our special case an analytical proof of horizontal convergence at the level of the polar tropopause is given by Fig. 7 which represents the trajectories of three elements of air which were at 1800 on November 9 over Larkhill, Liverpool and Downham Market respectively. The successive positions on these trajectories determine triangular areas. At a first approximation of Green's theorem it can be stated that the shrinking of these areas will be roughly proportional to the horizontal convergence in the moving air. On the diagram it can be seen immediately how important this effect is. Hence we can conclude that there must have been a strong vertical divergence which should have favoured a rapid dissipation of the polar tropopause.

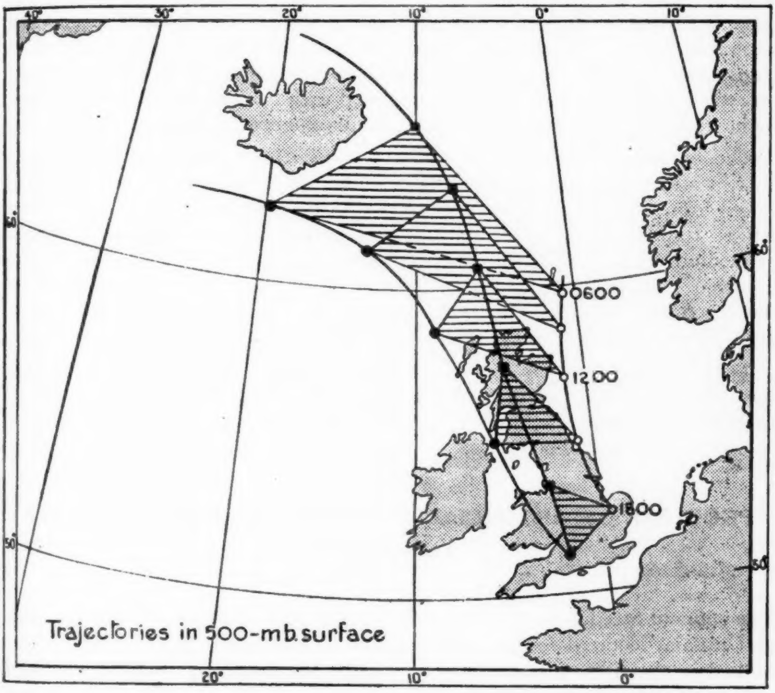

FIG. 7—TRAJECTORIES OF 3 ELEMENTS OF AIR WHICH WERE OVER LARKHILL, LIVERPOOL AND DOWNHAM MARKET AT 1800 ON NOVEMBER 9, 1944

It should be borne in mind that the frontal surface intersects the triangles; for the air parcel which moves through Downham Market is of polar origin, whilst the air which passes Larkhill and Liverpool is from a tropical air mass. Horizontal convergence is always associated with an active front which could

otherwise not resist the dissipating effect of turbulence. At a higher level, in the 300-mb. surface, the entire sheet of air over the three stations is of tropical origin. It has been shown in Fig. 3 that at this height the air over Downham Market came also on an anticyclonically curved path from the Iceland region. The three trajectories in that surface are nearly parallel, and in view of the inaccuracy of the upper air charts it is not possible to state with confidence whether shrinking or spreading occurred. However, any change in the 300-mb. surface is incomparably smaller than the rate of the horizontal shrinking at the 500-mb. level and it cannot affect materially the tropopause in the tropical air.

General deduction.—In the preceding investigation of a special case it has been established that tropospheric air of tropical origin over-ran stratospheric air of polar origin. In the subsequent development the lower polar branch of the tropopause was dissipated, and the stratospheric air masses were thus drawn into the tropospheric circulation. Synoptic situations of a similar type are relatively frequent, and it appears reasonable to assume that they will often produce a similar effect. We are justified in generalising that stratospheric air will be transformed into tropospheric air and ozone will be transported into the troposphere during synoptic situations which are characterised by an outbreak of cold air, associated with a rapid anticyclonic development and with the presence of tropical air at great altitudes.

The opposite transformation which has been investigated in Norway can be expected above old occluded depressions. In these vortices tropical air is raised from the ground and comes finally into a position above a polar tropopause. In this case there will be vertical convergence and horizontal divergence at medium levels, which will cause the polar tropopause to become more pronounced. Radiational conditions presumably tend in this case to transform the raised tropical air into polar stratospheric air. In this way a certain amount of water vapour, dust and carbon dioxide is transported into the stratosphere.

The dissipation of one branch of an overfolded tropopause will interrupt the initial continuity of that surface and produce the laminar structure of a multiple tropopause which has been described by several investigators (*e.g.* Bjerknes and Palmén).

PROBLEM OF ARTIFICIAL CONTROL OF RAINFALL OVER THE GLOBE

By Dr. TOR BERGERON

The eminent Swedish meteorologist Dr. Tor Bergeron, Professor of meteorology at Uppsala, lectured to the staff of the Meteorological Office on the subject quoted in the title on September 15, 1949. Dr. Bergeron's lecture was based on his articles of the same title in *Tellus*, **1**, No. 1 and No. 3. Only a brief report can be given here. The Director, in introducing Dr. Bergeron, referred to him as a great authority, possibly the authority, on processes of the releasing of precipitation from clouds.

Dr. Bergeron opened by saying that there was now a possibility of controlling the weather to some extent, and that he did not suppose the problems of doing so would be found any less difficult by meteorologists than those of forecasting it.

So far the only attack had been on the inducing of precipitation by dropping artificial nuclei into the clouds, though in time man might, for instance, warm the oceans by atomic energy to promote evaporation.

He pointed out that in general only those cloud forms which had a composition such that there were marked differences between the individual particles so that some particles tended to evaporate and others to grow by condensation (thermodynamic instability) were capable of producing appreciable precipitation, and further, this state necessitated the presence of water in all three phases at a temperature below 0°C. in order to be quite efficient. Slight thermodynamic instability can exist in clouds composed wholly of water-drops, owing to temperature differences, but serious instability demands the co-existence of ice crystals and supercooled water-drops. Natural formation of ice particles occurs at temperatures below, say, —10°C. The effectiveness of ice particles, whether natural or artificial, in producing rapid diffusion of the water of the supercooled droplets on to themselves and their subsequent precipitation depends partly on the temperature but largely on the ratio of the number of droplets to the number of ice crystals in a given volume. If this ratio is low ($\leqslant 1$) the cloud will presumably be rapidly transformed into one composed of many little ice crystals, as in cirrostratus, and of no value for precipitation (overseeding), and if it is high (10^9) the small number of ice crystals will certainly grow rapidly but they will soon fall out producing insignificant precipitation. The optimum ratio is not determined yet but may be about a thousand.

Artificial seeding has little or no value for producing precipitation from ordinary stratiform clouds, since the condensation process within them is too feeble. Seeding also has little value in the case of cumulus, since clouds which do not extend above the freezing level are unaffected, and those which do extend above the freezing level usually precipitate naturally. The seeding of frontal clouds is hardly practicable, since it would involve lengthy and widespread seeding. The best prospect for seeding seems to be with cloud produced by strong upward motion more or less fixed in space and extending above the 0°C. level but not reaching the —10°C. level. These conditions are fulfilled by some kinds of orographic cloud, and to these Dr. Bergeron next directed attention.

He pointed out that for heavy precipitation there must be a releasing region within a cloud or a cloud system to produce the necessary ice nuclei for seeding and a producing region below it where great amounts of condensed water are made available for seeding and precipitation. Outside the tropics very heavy precipitation requires low cloud formed by an intense updraft at high temperature in continual contact with an upper cloud or part either above the —10°C. level or artificially seeded. In the ordinary cumulonimbus these regions are part of the same cloud but this need not be so in every case.

The possible association of these two regions with separate cloud systems was well demonstrated by the very heavy precipitation over the coast of south-east Norway on March 24–27, 1927. On this occasion the seeding region was an upper frontal cloud system associated with a front well to the south-west and not, in itself, producing much precipitation over southern Scandinavia. The producing region was the cloud formed in a strong low-level air stream

forced to flow from north-east along the coast of south-east Norway as it was too stable to flow up over the main mountain range. The cloud in this north-east flow was formed by frictional convergence in a stream flowing roughly along the topographic contours. Neither system by itself would have produced the fall of snow equivalent to 201 mm. (7·9 in) of water which fell in the three days at a point on the coast.

Dr. Bergeron then turned to an even more striking illustration of orographic precipitation. He explained that frictional convergence, in statically stable air streams flowing roughly parallel to even a low coast line with higher pressure over the land, can produce a coastal maximum of precipitation. This was well illustrated by the heavy maximum of precipitation over the coastal dunes of Holland on October 25–26, 1945. Next day the wind changed to WSW. behind a cold front, the air became unstable and the distribution of precipitation quite different.

Such orographic cloud systems if lacking an efficient natural release or region represent just the clouds in which artificial seeding might materially increase precipitation because condensation may for a long while remain strong and stationary. However, an increase in coastal precipitation would diminish precipitation inland where it is more useful, so that it would be better, if possible, to overseed coastal cloud systems so that a coastal maximum is avoided and try to have the most efficient ratio of ice particles to water droplets further inland to ensure that the generally drier inland regions obtain a good supply of moisture and an effective release of precipitation. The lecturer drew attention to the difficulties, both technical and political, which attempts to regulate precipitation in this way were liable to create.

Dr. Bergeron pointed out that it was known that the ordinary theory of orographic precipitation which gave an increase with height was not in many cases supported by the evidence, several cases of which he quoted, *e.g.* the case of March 1927 just mentioned, but until the modern ideas on cloud structure were developed it was not possible to make a rational attack on the problem.

Dr. Bergeron concluded his lecture by showing a number of beautiful coloured slides taken by himself illustrating numerous cloud types from mother-of-pearl clouds down to frontal low cloud with rain, the changes which take place in visibility in central Sweden with change of air mass, and others of meteorological and scenic interest taken in the United States.

The Director, thanking Dr. Bergeron for his lecture, said he had given his hearers much to think about, and mentioned the apparent simplicity of the work described, once it had been thought out by the master.

INSTITUTE OF NAVIGATION

Two papers by members of the Meteorological Office were read at a meeting of the Institute of Navigation held at the Royal Geographical Society on May 20, Sir Robert Watson-Watt in the Chair. The first paper entitled "Equivalent headwinds on air routes" by A. F. Crossley was read by Mr. N. E. Davis. The work which this paper describes originated from requests from aircraft designers and from planning sections of air lines, notably British Overseas Airways Corporation, for wind information on world air routes at heights up to 40,000 or even 50,000 ft. The first thing was to prepare seasonal charts of contours of pressure surfaces at 700, 500, 300 and 200 mb. from which the mean

vector wind at any point could be obtained by application of the geostrophic formula, supplemented within the tropics by charts of mean stream-lines and isopleths of speed; also charts of the standard vector deviation of wind were prepared for the same levels. This work was carried out by C. E. P. Brooks, C. S. Durst and others, and is being published as *Geophysical Memoirs* No. 85. The charts express the basic wind information at any point in terms of only two variables, the mean vector wind and the standard vector deviation. The application of information of this type to provide statistics of wind on air routes in a form suitable for immediate application to air operations was worked out by A. F. Crossley and J. S. Sawyer, and a detailed account will be found in *Meteorological Reports* No. 6, now in the press. The present paper is for the most part a simplified account of that report.

An equivalent headwind (or tailwind) on an air route is defined as that constant wind which, directed everywhere along the track, results in the same ground speed as that attained with the actual system of winds. The paper shows how to calculate the mean equivalent headwind over a route in any season from the basic charts mentioned above, and further the calculation of the frequency distribution of equivalent headwinds was explained. Thus the planner is provided for any route with a seasonal mean value and also with the values of equivalent headwinds exceeded on any specified percentage of occasions. In this way he obtains the effective wind for which allowance has to be made in maintaining any required regularity of service. The calculations are generally made for an assumed airspeed of 200 kt., but the results apply with little or no variation to a range of about 150 to 300 Kt.; for higher airspeeds and suitable modification is required. Slides were shown illustrating the calculations and results for a route across the North Atlantic, and also showing a comparison between the statistical estimates and equivalent headwinds actually experienced by British Overseas Airways Corporation. Among several contributors to the discussion, Mr. E. Gold questioned the accuracy of the charts of stream-lines in the tropics where so few observations are available, and Mr. E. S. Willey of British South American Airways asked for information on the accuracy of estimates of equivalent headwinds. Replying to the discussion, Mr. Crossley said that the charts of tropical stream-lines were based on all available information and care was taken that, together with the pressure contour charts of the world, they presented a self-consistent picture of the distribution of wind. Mr. Durst remarked that although the charts were admittedly imperfect they had to be produced and were the best that could be made with present data, but they would be improved later when more upper air information had come to hand. Mr. Crossley went on to say that figures for equivalent headwinds over a route of length 1,000 miles or more would be more accurate than the values of mean winds at particular points. It was considered from experience of a few comparisons with operating statistics that the mean equivalent headwind in a season was in general correct to within 5 kt. at 10,000 ft. and to within 10 kt. at 20,000 ft. but that greater errors might occur at higher levels.

The second paper on "Jet streams and their importance to navigation" by C. S. Durst and N. E. Davis was read by Mr. Durst. A jet stream was defined as a very fast-moving stream of air found at levels between about 15,000 and 40,000 ft. The high velocity extends for a great distance downwind, but laterally there is a sharp decrease across the borders of the jet, especially

on the poleward side, where in some cases the speed falls off by as much as 100 kt. in 100 miles. In the vertical the speed may increase by 80 kt. in a height interval of 12,000 ft. below the centre of the jet, but there may be still more abrupt changes elsewhere. The movement of the stream itself consists of an extension downwind combined with a slow transverse displacement of the order of 10 kt. Synoptically, jet streams are found in the upper troposphere of middle latitudes on the warm-air side of the frontal surface between tropical and polar air masses, and the most rapid change in wind speed occurs at the passage through the frontal surface. To obtain the close juxtaposition of tropical and polar air it is necessary to have either a closed cyclonic circulation aloft in the polar air or a closed anticyclonic circulation aloft in the tropical air, either of which entails a deep penetration of polar air into lower latitudes or of tropical air into higher latitudes. Mr. Durst said he first noticed these fast narrow streams while examining charts for 225 mb. over north-west Europe, but subsequently it was learned that similar features had recently been reported by meteorologists in the United States of America and the name jet stream had originated there. Diagrams of vertical sections tnrough jet streams and of corresponding synoptic charts were shown on the screen. From these it appeared that speeds of 100 kt. or more were to be expected in a jet, while the greatest speed shown in these diagrams was 178 kt. (Downham Market, January 3, 1943, at about 25,000 ft.).

The importance of jet streams in navigation and forecasting arose not only from the high wind speed but also from the small lateral extent of the jet, since on this account they can easily be either overlooked or their importance exaggerated according as to whether observations of wind are obtaiend from within them or not. Mr. Durst, referring to the dispersal of our aircraft during a certain mass raid on Berlin, said this was due to an unforeseen jet stream, and G./Capt. Barrett later commented that some of the winds found by the navigators on that raid were so unexpectedly high that they were disregarded, although they were actually correct.

Mr. E. Gold referred to a zeppelin raid against this country in 1917 when the airships were scattered southwards over France, and declared that that was the first case in which a jet stream had seriously interfered with military operations.

Mr. J. Durward claimed that the first measurement of wind speed in a jet stream occurred on October 22, 1925, when a pilot balloon released from Calshot was seen to fall four hours later at a point 570 miles to the east, giving an average speed for the flight of 143 m.p.h. and an inferred wind of 180–200 m.p.h. at 30,000–35,000 ft.

Mr. E. S. Willey asked if intense gustiness at high altitudes was associated with jet streams, and, in reply, Mr. Durst agreed that was to be expected on account of turbulence which would be set up by the strong shear on the poleward borders of the jet stream, but that nothing had yet been published on this.

An interesting and instructive meeting terminated after several other speakers had taken part in the discussion.

ERRATUM

SEPTEMBER 1949, page 264, line 5; *for* "$t_3 = 23{\cdot}47\, T_5 + 1{,}884$" *read* "$t_3 = 23{\cdot}47\, T_5 + 11{,}884$".

OFFICIAL PUBLICATION

The following publication has recently been issued:—

Percentage frequencies of various visibility ranges at certain places in the British Isles between the years 1927 and 1936.

The tables in this publication give the monthly, seasonal and annual percentage frequencies of the visibility ranges adopted by the International Commission for Air Navigation. The seasons are defined as Spring—March, April, May; Summer—June, July, August; Autumn—September, October, November; Winter—December, January, February. The stations used are the synoptic weather reporting stations of the British Isles with a few additional stations from which comparable observations were available, and the period covered is the ten years 1927 to 1936. For each station a table shows the frequencies of visibilities for the three hours, 0700, 1300 and 1800 G.M.T., and the distances of the actual visibility objects limiting the ranges are shown at the foot of the page.

LETTER TO THE EDITOR

Dust devils at Shawbury

In a letter published in the July *Meteorological Magazine* a description is given of dust devils at Dublin Airport. The following account of a similar phenomenon observed at Shawbury on July 12, may be of interest.

At 1400 G.M.T. an eddy was rendered visible approximately 70 yd. north of the meteorological office not by dust but by loose paper which was raised to a height of approximately 200 ft. The paper included large sheets of newspaper and a very marked cyclonic rotation was set up, the width of the cylinder being estimated to be about 30 ft. The phenomenon persisted at the same intensity for some ten minutes during which time it moved very little. At 1410 the eddy moved some 40 yd. to the north-west and collapsed rapidly.

The weather at the time was fair with 5 oktas of cirrus cloud and a north-easterly surface wind of 2 kt. The dry-bulb temperature was 85·1°F. with a wet-bulb temperature of 65·9°F.

Mr. D. Bright, a farmer, has since reported that a similar case occurred some ten miles to the north-west of Shawbury approximately half an hour earlier. While he was engaged in clearing a field of " rakings " from a mixed crop of oats, peas and vetches he observed an eddy with a counter-clockwise rotation, lifting the " rakings " to a height of some 60 ft., the width of the cylinder being estimated as 15 ft.

G. A. WILLIS

Shawbury, Shrewsbury, July 13, 1949

NOTES AND NEWS

Effect of heated glasshouses on minimum temperatures in a nearby screen

The Stevenson screen at Wye College is about 21 ft. west of the near wall of a large glasshouse running roughly north-north-east to south-south-west. This glasshouse is some 8 ft. high to the ridge, which is about 28 ft. from the

screen. A larger house runs parallel to the first; this is 18 ft. high to the ridge, which is about 66 ft. from the screen. These glasshouses are kept at 55–60°F. in winter and it was thought that the screen temperatures may be affected by their proximity. The effect was investigated in the following way.

It is known that the glasshouses were erected about 1935, and records from the screen are available for the period 1925–44. Average temperatures for Wye are published in "Averages of temperature for the British Isles for the periods ending 1935", and deviations of the mean daily minima from their respective averages were computed for each of the months November to April over the period 1925–44. The average daily minimum (1925–35) for each of these months is below 40°F. and it was considered that any effect would be most marked then. Similar data are available for East Malling and the deviations for this station were also computed. The differences between these deviations (Wye *minus* East Malling) were tabulated for the two 10-year periods 1925–34 and 1935–44. The frequency of positive values of these differences in each month is given below.

	November	December	January	February	March	April
1925–34	4	6	4	5	3	4
1935–44	6	8	8	7	8	9

These values suggest an increase in the minima at Wye after 1934 and a *t*-test was applied to the differences to determine whether the mean value was significantly different in the two periods. This test is described by R. A. Fisher*. It showed that the mean daily minimum at Wye over the months November to April was increased by nearly 0·4°F. after the glasshouses were erected, and the difference was significant at the 0·01 level.

Winds from between NE. and SE. blow over the glasshouses before reaching the screen. To determine whether the effect was related to wind direction, the correlation coefficient was calculated between the differences (Wye *minus* East Malling) and the monthly frequency of winds from these directions. This coefficient is only about ·10 and is not significant. This is hardly surprising as the screen may be heated by radiation from the glasshouse. Also convective heating of the air near the screen may be just as great with westerly as with easterly winds because of the eddies set up by the glasshouse.

Possibly a similar effect occurs in screens near houses with central heating.

W. H. HOGG

University College, London, Meteorological Society

A meteorological society has been formed in University College, London, around a nucleus of staff and students who were formerly members of the Meteorological Office. Functions already held include a visit to the Central Forecasting Office and a lecture by Mr. P. J. Meade on recent changes in meteorological practice.

Anyone connected with the University of London who is interested in attending future meetings of the Society is invited to communicate with "The Secretary, Meteorological Society, University College, London Union, Gower Street, London, W.C.1."

---

*FISHER, R. A.; Statistical methods for research workers. London, 10th edn., 1946, p. 122.

NEWS IN BRIEF

The L.G. Groves Memorial Prize for Meteorology has been awarded this year to Mr. C. S. Durst, B.A., Senior Principal Scientific Officer in the Meteorological Office, for successfully carrying out many important investigations into meteorological problems affecting the safety and efficient performance of Royal Air Force aircraft. During the past year Mr. Durst has produced seven important papers relating to wind at high levels over the whole globe. His work displays an exceptional ability in applying sound scientific methods to his problems, and in presenting the results in an essentially practical form.

The L. G. Groves Memorial Award for Meteorological Air Observers has been won this year by Sergeant R. T. D. Scott, R.A.F., for his zealous work as Meteorological Air Observer, No. 224 Squadron, Gibraltar, which has earned the highest praise. Sergeant Scott has maintained a standard of observational accuracy to a high order, and by his efforts has made a valuable contribution to the technical efficiency of the meteorological reconnaissance flights.

OBITUARY

Professor Antonino Lo Surdo.—We regret to report the death in Rome on June 7, 1949, of Professor A. Lo Surdo, aged 69 years, Founder and Director of the Italian National Institute of Geophysics and of the associated journal *Annali di Geofisica*. He was also Director of the Physical Institute of the University of Rome.

Professor Lo Surdo carried out important researches in several branches of geophysics, notably in seismology and the question of the effective radiating temperature of the sky. He worked also in other branches of physics, and was the discoverer of the splitting of spectral lines by an electric field (Lo Surdo and Stark effect).

WEATHER OF SEPTEMBER, 1949

Mean pressure was above 1015 mb. over most of Europe and over the United States (except the south-west) as well as over the North Atlantic from about 50°N. to at least 30°N. It was above 1020 mb. over the Azores and for a considerable distance westward of the Azores, also from southern Sweden and the Baltic to Austria, Hungary and Rumania. Regions with the mean appreciably below 1010 mb. were to be found only in Alaska and Spitzbergen.

Mean pressure was above normal over most of Europe, most of the northern part of the North Atlantic and the Mediterranean, the excess being from 5 to 8 mb. over Scandinavia and the Baltic. In North America deviations from normal were small.

The weather over the British Isles was characterised by exceptional warmth. At a number of stations with long records it was the warmest September on record, for example, at Oxford since 1815, at Kew Observatory since 1871. At Southport it was the warmest September since their record warm September in 1895. The nights, in particular, were exceedingly warm. The month was dry on the whole, apart from heavy local falls of thundery rain, sunnier than the average in most places and somewhat quieter than usual, particularly in northern districts.

During the first six days of the month a depression was situated north-west or west of the British Isles and troughs of low pressure or secondary depressions swung round it across the British Isles. Warm weather prevailed and rain fell at times in most areas, but the amounts were variable, while sunshine records were moderately good. High day temperatures were registered, particularly

on the 4th and 5th, among the highest readings being 91°F. at Maldon and 90°F. at Shoeburyness, Cromer, Belstead and Mildenhall on the 5th. The night of the 4th–5th was exceptionally warm; the minimum temperature on the 5th was 69°F. at Oxford and 67°F. at Kew, both record high minima for September. There were scattered thunderstorms during this period, the storms being widespread on the 4th and 5th. Thereafter from the 7th to 9th a belt of high pressure extended from the anticyclone north of the Azores across southern England and France, while small depressions moved north-east across our northern seaboard; some rain fell in the west and north. On the 10th and 11th a trough associated with a depression centred to the north moved very slowly south-east across the British Isles; rain, mainly slight, fell locally in Ireland and Scotland on the 10th but it was fair generally on the 11th. On the 12th an anticyclone north of Scotland moved east, while a trough of low pressure off our south-west coasts moving north-east gave rain later in the extreme south-west. This trough subsequently moved north across the country, causing heavy rain locally in the south of England on the 13th and in south and east Britain on the 14th. On the 15th another small secondary depression over Cornwall moved north-east; rain fell in most places on the 15th and locally, chiefly in the north, on the 16th.

Subsequently a wedge of high pressure moved in over the British Isles and, thereafter, until the 21st, pressure was high in a belt extending across Scotland to Norway. Meanwhile a trough to a depression off our south-west coasts extended from south-west Ireland to north France, where it remained almost stationary for several days; heavy rain occurred in south-west England on the 20th and 21st, over 2 in. being registered at stations in Cornwall on the 20th and at numerous places in Dorset on the 21st (2·44 in. at West Looe on the 20th and 2·79 in. at Creech Grange on the 21st). Subsequently the trough moved slowly north on the 22nd and 23rd, giving rain and local thunderstorms, particularly in England, Wales and east Scotland. More than 2 in. was recorded at a number of places in the southern half of England and Wales on the 22nd, for example 2·96 in. at Presteign, Radnor, of which roughly $2\frac{3}{4}$ in. fell in 80 minutes, 2·66 in. at Chipping Norton, Oxon, and 2·59 in. at Bridgend, Glam. On the 24th a new depression south of Iceland moved south-south-east; rain fell in England and Wales, Ireland and south Scotland, with local thunderstorms but the rainfall was not generally very heavy.

Thereafter conditions were mainly anticyclonic; from the 25th–29th a large anticyclone over central Europe maintained fair weather, apart from mist or fog, over most of the British Isles, and on the last day a ridge associated with an anticyclone in mid Atlantic extended over this country.

The general character of the weather is shown by the following provisional figures :—

	Air Temperature			Rainfall		Sunshine	
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average	Percentage of possible duration
	°F.	°F.	°F.	%		%	%
England and Wales ..	91	36	+5·4	80	−4	105	39
Scotland	80	26	+4·0	74	−4	110	33
Northern Ireland ..	73	36	+3·9	90	−5	121	38

RAINFALL OF SEPTEMBER 1949

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ..	·36	20	*Glam.*	Cardiff, Penylan ..	3·65	120
Kent	Folkestone, Cherry Gdn.	3·08	130	*Pemb.*	St. Ann's Head ..	1·11	39
"	Edenbridge, Falconhurst	·92	41	*Card.*	Aberystwyth	2·10	74
Sussex	Compton, Compton Ho.	2·71	97	*Radnor*	Tyrmynydd	2·69	70
"	Worthing, Beach Ho.Pk.	1·69	79	*Mont.*	Lake Vyrnwy	1·74	46
Hants	Ventnor, Roy. Nat. Hos.	3·75	151	*Mer.*	Blaenau Festiniog ..	2·57	33
"	Bournemouth	4·44	190	*Carn.*	Llandudno	·56	26
"	Sherborne St. John ..	2·51	122	*Angl.*	Llanerchymedd ..	2·01	68
Herts.	Royston, Therfield Rec.	·43	23	*I. Man.*	Douglas, Borough Cem.	2·27	69
Bucks.	Slough, Upton	·87	49	*Wigtown*	Port William, Monreith	2·38	82
Oxford	Oxford, Radcliffe ..	2·29	134	*Dumf.*	Dumfries, Crichton R.I.	1·91	70
N'hant.	Wellingboro', Swanspool	1·29	72	"	Eskdalemuir Obsy. ..	2·69	73
Essex	Shoeburyness	1·45	84	*Roxb.*	Kelso, Floors	1·26	66
Suffolk	Campsea Ashe, High Ho.	1·56	82	*Peebles*	Stobo Castle	1·98	79
"	Lowestoft Sec. School ..	1·87	95	*Berwick*	Marchmont House ..	1·49	62
"	Bury St. Ed., Westley H.	1·01	51	*E. Loth.*	North Berwick Res. ..	·95	45
Norfolk	Sandringham Ho. Gdns.	1·35	65	*Midl'n.*	Edinburgh, Blackf'd. H.	1·75	85
Wilts.	Bishops Cannings ..	1·07	49	*Lanark*	Hamilton W. W., T'nhill	1·29	48
Dorset	Creech Grange.. ..	7·30	266	*Ayr*	Colmonell, Knockdolian	2·86	82
"	Beaminster, East St. ..	4·74	186	"	Glen Afton, Ayr San ..	2·37	61
Devon	Teignmouth, Den Gdns.	2·75	140	*Bute*	Rothesay, Ardencraig	2·56	63
"	Cullompton	4·93	219	*Argyll*	L. Sunart, Glenborrodale	3·00	48
"	Barnstaple, N. Dev. Ath.	1·90	70	"	Poltalloch	2·39	52
"	Okehampton, Uplands	3·28	101	"	Inveraray Castle ..	4·14	64
Cornwall	Bude, School House ..	3·96	160	"	Islay, Eallabus ..	3·77	90
"	Penzance, Morrab Gdns.	2·20	75	"	Tiree	3·44	93
"	St. Austell, Trevarna ..	4·70	147	*Kinross*	Loch Leven Sluice ..	2·71	105
"	Scilly, Tresco Abbey ..	4·63	181	*Fife*	Leuchars Airfield ..	1·59	82
Glos.	Cirencester	1·46	66	*Perth*	Loch Dhu	3·55	62
Salop.	Church Stretton ..	1·89	90	"	Crieff, Strathearn Hyd.	1·17	41
"	Cheswardine Hall ..	·65	32	*Perth*	Pitlochry, Fincastle ..	1·19	47
Worcs.	Malvern, Free Library	1·64	85	*Angus*	Montrose, Sunnyside ..	1·87	94
Warwick	Birmingham, Edgbaston	1·11	62	*Aberd.*	Braemar	1·75	70
Leics.	Thornton Reservoir ..	1·67	92	"	Dyce, Craibstone ..	1·91	79
Lincs.	Boston, Skirbeck ..	1·65	94	"	Fyvie Castle	1·36	52
"	Skegness, Marine Gdns.	1·25	69	*Moray*	Gordon Castle	2·47	99
Notts.	Mansfield, Carr Bank ..	1·02	55	*Nairn*	Nairn, Achareidh ..	1·01	48
Derby	Buxton, Terrace Slopes	1·48	46	*Inv's*	Loch Ness, Foyers ..	1·53	52
Ches.	Bidston Observatory ..	·85	35	"	Glenquoich	..	..
Lancs.	Manchester, Whit. Park	·56	24	"	Fort William, Teviot ..	4·94	77
"	Stonyhurst College ..	1·86	49	"	Skye, Duntuilm ..	4·39	95
"	Blackpool	·84	29	*R. & C.*	Ullapool	2·75	76
Yorks.	Wakefield, Clarence Pk.	1·26	79	"	Applecross Gardens ..	5·15	103
"	Hull, Pearson Park ..	1·12	65	"	Achnashellach	6·69	97
"	Felixkirk, Mt. St. John	·49	27	"	Stornoway Airfield ..	3·42	91
"	York Museum	·80	49	*Suth.*	Lairg	..	..
"	Scarborough	·93	52	"	Loch More, Achfary ..	6·95	121
"	Middlesbrough.. ..	·60	36	*Caith.*	Wick Airfield	2·38	95
"	Baldersdale, Hury Res.	1·94	78	*Shetland*	Lerwick Observatory ..	2·79	93
Norl'd.	Newcastle, Leazes Pk. ..	·72	36	*Ferm.*	Crom Castle	2·23	80
"	Bellingham, High Green	1·93	80	*Armagh*	Armagh Observatory ..	2·47	100
"	Lilburn Tower Gdns. ..	2·04	86	*Down*	Seaforde	2·96	108
Cumb.	Geltsdale	1·21	43	*Antrim*	Aldergrove Airfield ..	1·93	78
"	Keswick, High Hill ..	2·07	49	"	Ballymena, Harryville..	2·48	80
"	Ravenglass, The Grove	2·60	77	*L'derry*	Garvagh, Moneydig ..	3·12	105
Mon.	Abergavenny, Larchfield	3·21	137	"	Londonderry, Creggan	2·34	71
Glam.	Ystalyfera, Wern House	2·75	63	*Tyrone*	Omagh, Edenfel ..	3·07	101

CLIMATOLOGICAL TABLE FOR THE BRITISH COMMONWEALTH, MAY 1949

Stations	Pressure: Mean of day M.S.L.	Pressure: Diff. from normal	Temperatures: Absolute Max.	Temperatures: Absolute Min.	Temperatures: Mean values Max.	Temperatures: Mean values Min.	Temperatures: Mean values ½ Max. and Min.	Temperatures: Mean values Diff. from normal	Temperatures: Mean values Wet bulb	Relative humidity	Mean cloud amount	Precipitation: Total	Precipitation: Diff. from normal	Precipitation: Days	Bright Sunshine: Daily mean	Bright Sunshine: Percentage of possible
	mb.	mb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	oktas	in.	in.		hr.	%
London, Kew Observatory	1015.3	+0.3	69	35	61.7	45.1	53.4	−1.3	48.1	70	5.2	2.30	+0.58	12	7.0	45
Gibraltar	1014.8	−1.3	81	52	73.3	59.1	66.2	+0.7	60.5	70	4.0	0.34	—	11	10.1	72
Malta	1012.8	−1.7	80	55	73.0	59.6	66.3	+0.4	62.6	66	3.7	0.52	—	4	9.9	71
St. Helena	1016.0	−0.9	75	57	70.2	59.9	65.1	+2.5	59.8	94	6.1	5.34	+2.80	17	—	—
Lungi, Sierra Leone	1011.9	—	91	73	88.2	76.7	82.5	—	76.3	78	5.9	5.07	—	11	6.8	54
Lagos, Nigeria ..	1011.1	+0.5	95	70	90.5	73.5	82.0	+0.2	78.4	79	6.6	7.36	—	14	6.3	51
Kaduna, Nigeria ..	1008.3	—	95	65	88.6	71.3	79.9	0.0	74.1	80	6.3	4.11	−1.59	13	7.8	62
Chileka, Nyasaland	1019.0	−0.1	88	55	77.9	61.2	69.5	+1.5	62.2	71	3.6	0.60	+0.30	7	6.3	55
Lusaka, Rhodesia ..	1017.1	0.0	86	48	78.9	55.4	67.1	+2.0	58.0	70	2.9	0.51	+0.46	1	8.8	77
Salisbury, Rhodesia	1019.2	−0.2	83	41	73.5	50.5	62.0	+0.9	54.3	70	2.7	0.90	+0.52	5	7.4	65
Cape Town	1018.0	−0.1	92	39	70.2	50.0	60.1	+1.2	49.9	74	4.5	1.63	−2.12	18	—	—
Palmiefontein, S. Africa	1024.6	—	75	31	67.9	38.0	52.9	—	42.9	73	1.0	0.05	—	2	9.7	—
Mauritius																
Calcutta, Alipore Obys.	1004.0	+0.4	102	69	92.2	77.6	84.9	−1.2	79.3	77	5.1	10.32	+4.76	16	8.2	62
Bombay	1005.3	−2.1	94	76	92.2	80.5	86.3	+0.5	78.5	74	4.7	0.98	+0.43	6	9.1	69
Madras	1005.0	−0.4	105	75	96.5	81.1	88.8	−1.0	77.7	66	4.7	7.95	+6.11	5	8.0	63
Colombo, Ceylon ..	1008.7	+0.3	90	73	87.0	76.8	81.9	−0.9	77.6	83	6.1	12.62	+1.48	20	6.5	52
Singapore	1008.7	0.0	90	73	87.5	75.6	81.5	−0.5	77.3	83	5.4	8.88	+2.24	17	—	—
Hongkong	1010.5	+1.4	89	69	83.6	75.2	79.4	+2.0	74.7	82	—	4.57	+7.50	10	5.3	40
Sydney, N.S.W. ..	1020.6	+2.0	77	43	66.7	52.5	59.6	+0.8	53.8	80	5.3	4.01	−1.17	14	5.8	56
Melbourne	1020.9	+1.7	72	32	59.6	45.2	52.4	−1.7	48.1	79	5.6	2.51	+0.35	16	3.2	32
Adelaide	1022.2	+2.0	72	42	63.2	48.8	56.0	−2.0	51.0	67	6.0	2.05	−0.67	14	4.1	40
Perth, W. Australia	1021.4	+3.0	84	43	70.7	51.7	61.2	+0.5	56.0	65	3.0	0.77	−4.20	6	7.4	71
Coolgardie	1022.5	+3.4	84	37	68.3	46.0	57.1	−0.6	49.7	64	2.9	0.30	−1.03	4	—	—
Brisbane	1019.6	+1.0	80	45	72.8	54.2	63.5	−1.1	57.1	65	3.4	1.68	−1.13	9	7.5	69
Hobart, Tasmania	1019.9	+4.6	75	33	56.1	43.5	49.8	−0.7	44.7	73	6.5	2.40	+0.50	18	3.1	32
Wellington, N.Z. ..	1023.0	+7.7	65	36	57.1	46.3	51.7	+0.3	48.7	84	5.9	3.19	−1.49	12	4.1	41
Suva, Fiji	1013.1	+0.4	87	69	80.8	72.7	76.7	+0.2	73.9	86	6.8	36.13	+26.06	26	2.5	22
Apia, Samoa ..	1011.0	+0.3	89	71	86.6	73.9	80.3	+0.6	76.9	79	4.8	11.57	+5.04	20	7.1	62
Kingston, Jamaica	1013.5	+0.4	89	70	87.7	72.9	80.3	+0.6	74.7	75	4.0	3.35	−1.04	8	7.9	61
Grenada, W. Indies	—	—	90	71	87.0	74.0	80.5	+0.8	77.0	89	5.0	2.88	−1.31	11	—	—
Toronto	1016.3	+1.4	89	37	69.0	47.1	58.1	+4.3	46.8	65	5.0	0.41	−2.38	7	8.9	61
Winnipeg	1014.5	+0.7	84	24	65.7	40.2	52.9	+0.9	41.7	77	7.5	1.71	−0.29	9	6.6	43
St. John, N.B. ..	1015.6	+1.7	76	35	55.9	41.8	48.9	+1.2	44.6	79	7.6	3.65	−0.08	13	7.2	48
Victoria, B.C. ..	1015.8	−0.9	74	33	64.4	45.0	54.7	+1.7	45.3	86	4.3	0.71	−0.42	7	10.2	67